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MEASUREMENTS OF UNDERCARRIAGE AND ENGINE MOUNTING REACTIONS DURING LANDINGS ON A "LANCASTER"

by

J. B. LAMBIE, M.Eng.

T.D.U. 510

Inclosure 12

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Technical Note No. S.M.E.375

August, 1946

ROYAL AIRCRAFT ESTABLISHMENT, FARNBOROUGH

Measurements of Undercarriage and Engine Mounting Reactions during Landings on a "Lancaster".

by

J.B. Lambie, M.Eng.

R.A.E. Ref: SME.C1/6627/JBL/93

SUMMARY

This report gives the results of resistance strain gauge measurements of undercarriage and engine mounting strains on a Lancaster aircraft during landing and taxying. Gauge resistance changes are converted into loads from the changes produced by known static loads when applied to the engine and undercarriage. The peak engine vertical deceleration is found to be greater than that which would occur if the same undercarriage reaction were applied to the rigid aircraft. This difference seems to be largely attributable to the rapid decrease of the drag on the wheels once they have been spun up, and it is evident from curves giving the time history of stress variation that the elastic properties of the aircraft structure are governing the stresses caused by the varying ground reactions. Spinning up the wheels before landing is suggested as a possible way of eliminating the extra deceleration on the engines caused by the rapid decrease of drag, and also of eliminating the oscillating drag and anti-drag loads which wheel inertia sets up in the undercarriage radius rod, etc. Such anti-drag forces should be considered in stress calculations.

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1 Introduction

These tests were made on a Lancaster aircraft to investigate the relationship between the ground reactions and the engine mounting reactions. Loads were measured in selected members of the undercarriage and engine mountings on one side of the aircraft by means of wire resistance strain gauges used in conjunction with the four way switch and cathode ray oscillograph arrangement described in Ref.1.

2 Gauge positions

As indicated in Fig.1 "vertical" reaction on the undercarriage was measured on both oleo sliding tubes of the port undercarriage by four gauges and four "dummy" gauges on unstressed strips of similar metal on each. "Drag" load was measured similarly by gauges on the radius rods, and engine mounting reactions by gauges on the two top horizontal members of the engine sub-frame as shown in Fig.2.

3 Calibration

3.1 Undercarriage "vertical" reaction

Vertical load was applied to the port undercarriage by raising and then lowering the aeroplane with hydraulic jacks, using the jacking points provided on the main spar. The tail was raised so that the aeroplane was in its flying attitude, and the angle between the front oleo legs of the undercarriage and the true vertical was then very small. The C.G. of the aircraft was afterwards determined by weighing and this gave the load applied in the test. The change in resistance of the gauges on the oleos due to this applied load was recorded and provides the calibration used for interpreting flight records as explained later. This procedure results in the "vertical" direction of reference coinciding with the direction of the oleo legs and not the true vertical, i.e. axes of reference are fixed relative to the aircraft and not the ground.

3.2 "Drag" Load

Drag load gauges on the radius rod were similarly calibrated in ohms per 1000 lb. by applying a load at the axle with a spring balance and a block and tackle so that the direction of the load was at right angles to the oleo legs. The aircraft was not jacked up for these tests but the brakes were kept off so as to minimise the drag load which could be transmitted to the ground. The "drag" measured by gauges calibrated in this way will be in a direction perpendicular to the oleo. It will virtually act at the position occupied by the axle when the aircraft is at rest on the ground and not the actual position while landing. The "drag" will also include the effect of any inertia load in the undercarriage caused by the true ground reaction.

3.3 Engine Mounting Calibration

Engine mounting gauge calibration was done by hanging a 1000 lb. weight on the engine nacelle so that its line of application passed through the C.G. of the power unit. Propeller thrust will also strain these gauges but this strain is negligible. The inner and outer nacelle longeron gauges were connected in series so as to cancel out sideload strains. Inertia loads due to pitching (angular) acceleration of the engines will also strain these gauges. This effect is not separated here from the vertical acceleration but is included in the measurement of the vertical acceleration.

A check on the engine mounting calibration was obtained during flight by putting the aircraft into a tight turn and holding it at a desired 'g'. This was found to be reasonably easy provided the tests were done in calm air. The results obtained agreed quite well with ground calibration results and are shown in Fig.3. The result of inserting 0.4 ohms and also of 2g turns is illustrated in this figure.

3.4 Calibrations in flight

In flight trials known resistances were switched into the vertical, drag and engine mounting gauge circuits and the deflection of the trace due to these resistances used in conjunction with the ground calibration results (which give the equivalent in ohms of an applied static load) provides the data required to turn the record traces into equivalent static loads. Detail results of the ground calibration are given in the Appendix since they may be useful to other workers who wish to use the films (which are available at the R.A.E.) to abstract more information than is given in the present note. Ground calibrations were repeated after the series of tests and found to agree with the calibrations done before the series of flights.

4 Results

The table which follows gives the maximum and minimum values of the undercarriage "vertical" and "drag" loads and the engine mounting loads which occur in the first touchdown period of a landing and while subsequently "taxying". The aircraft C.G. in the tests was 49.9 in. aft of the datum point. (Due to the fact that the sensitivity of the oscillograph was not quite linear over the oscillograph screen the scales on figures 5, 6, 7 and 8, which are tracings of the oscillograph records are not linear. The maximum values quoted in the table are calculated from calibrations of the measuring instrument done a few seconds before each touchdown and allow for this non-linearity).

The results shown in the table are plotted in Figs.4 (a) and 4 (b) for the initial touchdowns in which drag was present due to spinning up the wheels, and Figs.4 (c) and 4 (d) summarise the results for subsequent "taxying" impacts.

Figs.5, 6, 7 and 8 show four typical records, two at initial touchdown and two of taxying.

In the initial touchdown, Figs.5 and 6, the "drag" is seen to increase steadily to a maximum and then, probably when the wheels are spun up to aircraft speed, to decrease rapidly to a minimum. Then follows a damped fore and aft oscillation probably that of the undercarriage on the aircraft with the tyre in contact with the ground. When the drag suddenly decreases the engine accelerations are seen to increase, the inner engine being the first to do so and showing a greater increase than the outer engine. The elastic and inertia properties of the structure are evidently governing the reactions which are occurring. It will be observed that the airframe is subjected to anti-drag forces in the course of the landing. These arise from wheel mass inertia loads and have in the past not been considered in conventional stress calculations. A possible way of eliminating this anti-drag force in the undercarriage and the extra 'g' on the engines caused by the sudden decrease of drag is to spin up the wheels prior to landing.

5 Conclusions

The tests show that the vertical 'g' on the engine mounting may be greater than at the undercarriage and that the greatest engine accelerations on the Lancaster during landing occur at the initial touchdown just after the large drag force required to spin up the wheels disappears. Anti-drag forces due to wheel inertia are imposed on the airframe. Such forces should be considered in stress calculations.

Ref.	Author	Title
1	D.H. Peirson	The Method of High Speed Switching applied to Multiple Oscillograph Measurements and its adaption for Measurements in Flight. A.R.C. 9186 Sheet 964. S.M.E. Tech. Note No.309, April 1945.

Attached:

Appendix

Table

Figs.1 to 8 Drg. Nos. SME/15931/R to SME/15938/R.

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APPENDIX I

Results of Ground Calibrations.

1 Vertical load

Load applied = 23,610 lb. = 1W = ½ x all up weight.

1 ohm = 4.75 W.

2 Drag load

Load applied = 4000 lb.

1 ohm = 25,600 lb. = 1.08 W.

3 Engine mountings

1000 lb. applied at C.G. of each engine.

Weight of power unit = 2700 lb.

1 ohm = 2.78 g on inner engine

1 ohm = 3.70 g on outer engine

In calibrating the film record a resistance is switched into each channel in steps of 0.4 ohms so that each deflection obtained during this calibration is equivalent to 0.4 ohms. By applying this resistance calibration in conjunction with the above ground calibration to the subsequent record of the landing the values of the reactions occurring may be estimated.

TABLE I

Lancaster ED.872 - Engine Mounting and Undercarriage Reaction Results (Concrete runway with wood chip surface in parts).

Date	Pilot	Remarks	Undercarriage reactions ≁		Engine Mounting reactions **	
			Vertical	Drag	Outer	Inner
15.3.45	Ws	1st T.D.*	-	0.43 -0.39	2.4 -1.5	2.2 -1.1
15.3.45	Ws	1st T.D.	1.45	0.57 -0.33	- -	+3.3 -1.45
15.3.45	Ws	1st T.D.	1.56	0.68 -0.37	2.2 -1.6	1.9 -1.65
16.4.45	H	1st T.D.	1.53	0.87 -0.35	2.0 -0.52	2.05 -0.22
16.4.45	H	1st T.D.	1.28	0.46 -0.28	2.00 -0.30	1.9 -1.1
21.4.45	Wn	1st T.D.	0.9	0.40 -0.08	1.26 0.93	1.15 -1.1
21.4.45	Wn	1st T.D.	0.71	0.25 -0.08	1.33 -0.15	0.95 -0.55
21.4.45	Wn	1st T.D.	1.72	0.64 -0.24	1.63 -1.40	3.00 -3.00
11.5.45	H	1st T.D.	0.72	0.27 -0.08	0.63 -0.85	1.00 0.44
11.5.45	H	Taxying	0.72	-	1.17	1.05
11.5.45	H	Taxying	0.51	-	0.70	0.75
11.5.45	H	Taxying	1.00	-	1.10	1.00
11.5.45	H	Taxying	1.10	-	1.25	1.20
7.5.45	H	1st T.D.	1.66	0.47 -0.22	1.65 -0.66	1.89 -1.00
7.5.45	H	2nd T.D.	0.71	0.12	1.32	0.94
7.5.45	H	Taxying	1.10	-	0.58	0.33
7.5.45	H	Taxying	1.32	-	1.07	0.83
7.5.45	H	Taxying	1.11	-	1.07	1.11

*T.D. = Touchdown.

≁ In terms of the wheel load = 23,610 lb.

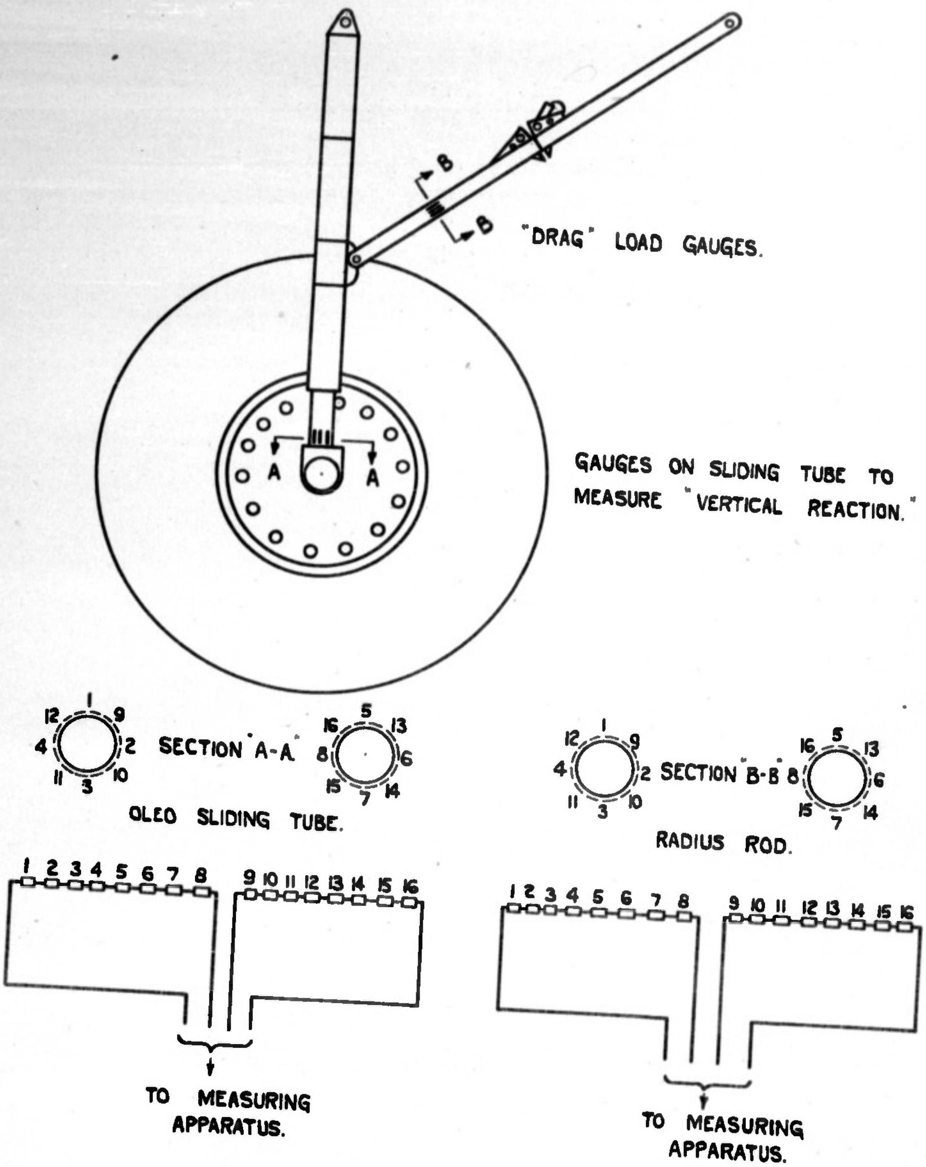
** In terms of engine wt. of 2700 lb.

TABLE I (Contd.)

Lancaster ED.872 - Engine Mounting and Undercarriage Reaction Results (Concrete runway with wood chip surface in parts).

Date	Pilot	Remarks	Undercarriage reactions ≠		Engine Mounting reactions **	
			Vertical	Drag	Outer	Inner
27.4.45	Ws	1st T.D.	1.95	0.45	1.63 -0.26	1.83 -1.22
		Taxying	2.3		1.22	1.00
		"	2.04		1.60	1.11
		"	1.83		1.22	0.95
		"	1.47		0.89	0.72
		"	1.83		1.22	0.95
		"	1.83		1.63	1.00
		"	1.83		1.33	0.89
		"	1.26		1.33	0.83
		"	0.98		1.15	0.78
		"	0.69		0.89	0.58
25.4.45	Ws	1st T.D.	2.1	0.60	2.60 -0.33	2.72 -1.25.
19.4.45	H	Taxying	1.05		1.15	0.97
		"	1.20		0.74	0.89
		"	0.83		0.81	0.86
		"	0.62		0.67	0.47
		"	0.85		0.61	0.55
		"	1.38		1.40	0.80
		"	1.04		0.81	0.86
		"	0.71		0.63	0.78
		"	0.85		0.55	0.42
19.4.45	Hs	1st T.D.	0.52	0.33	1.85 0.41	1.14 0.5
		Taxying	0.85		0.89	0.81
		"	0.47		0.41	0.39
		"	0.85		0.67	0.72

FIG. 1.



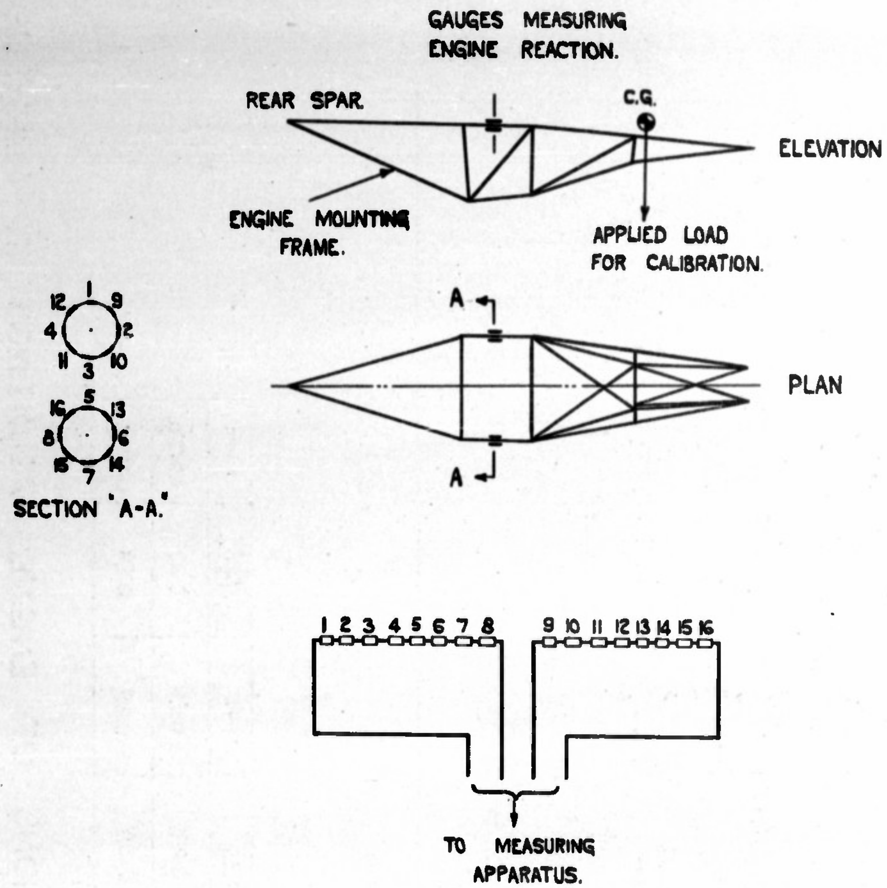
UNDERCARRIAGE GAUGES.

9

No. S.M.E. 15932/R.

T.N. S.M.E. 375.

FIG. 2.



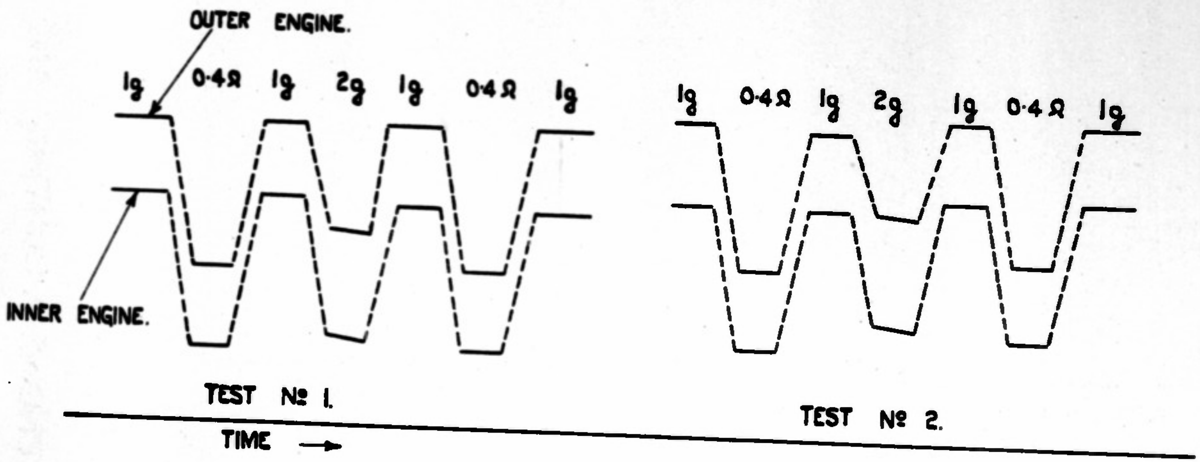
ENGINE MOUNTING GAUGES.

10

No. S.M.E. 15933/R.

T.N. S.M.E. 375.

FIG. 3.



	TEST 1	TEST 2	GROUND CALIBRATION	UNITS
OUTER ENGINE	0·29	0·26	0·27	OHMS/g
INNER ENGINE	0·38	0·35	0·36	OHMS/g

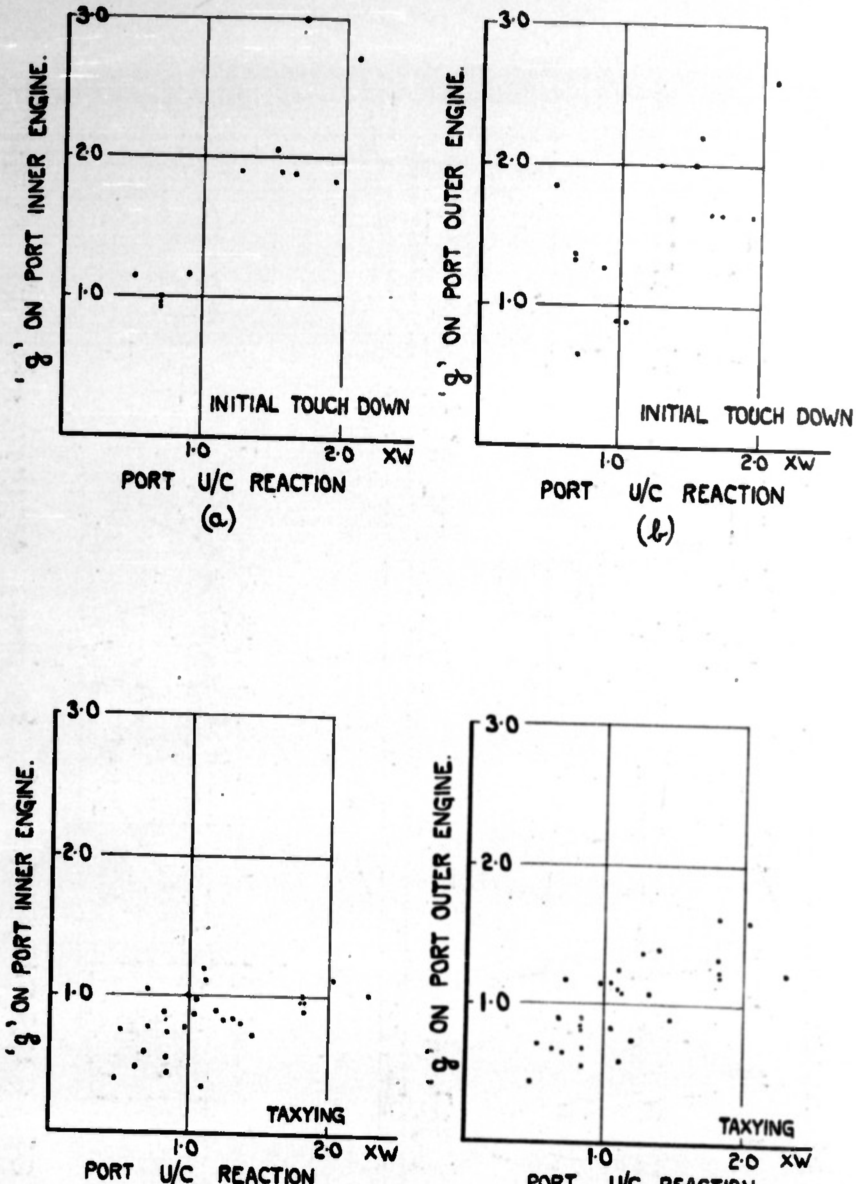
RESULTS OF CALIBRATIONS OF ENGINE MOUNTINGS IN FLIGHT COMPARED WITH CALIBRATIONS ON GROUND (LANCASTER E.D. 872.)

11—

No. S.M.E.15934/R.

T.N. S.M.E.375.

FIG. 4.

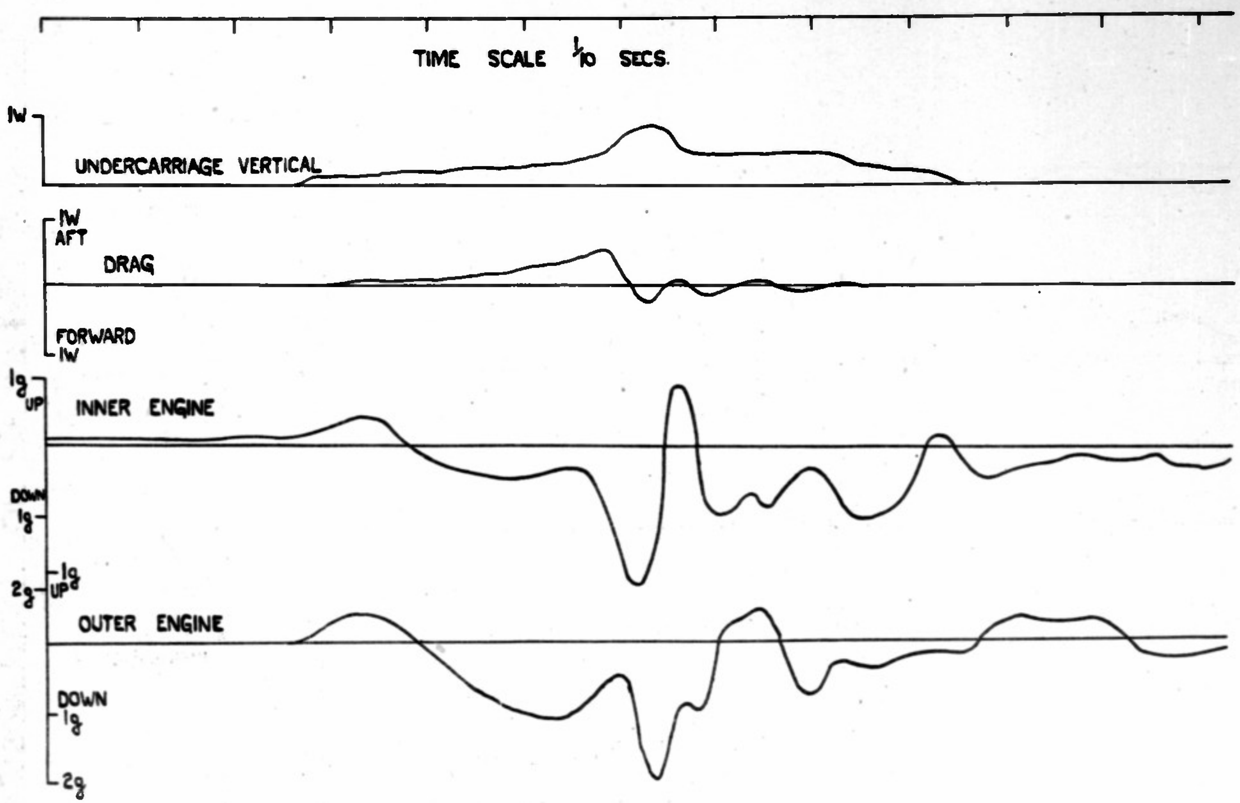


MEASUREMENT OF ENGINE MOUNTING AND UNDERCARRIAGE REACTIONS ON LANCASTER ED.872.

No S.M.E. 15935/R.

T.N. S.M.E. 375.

FIG. 5.

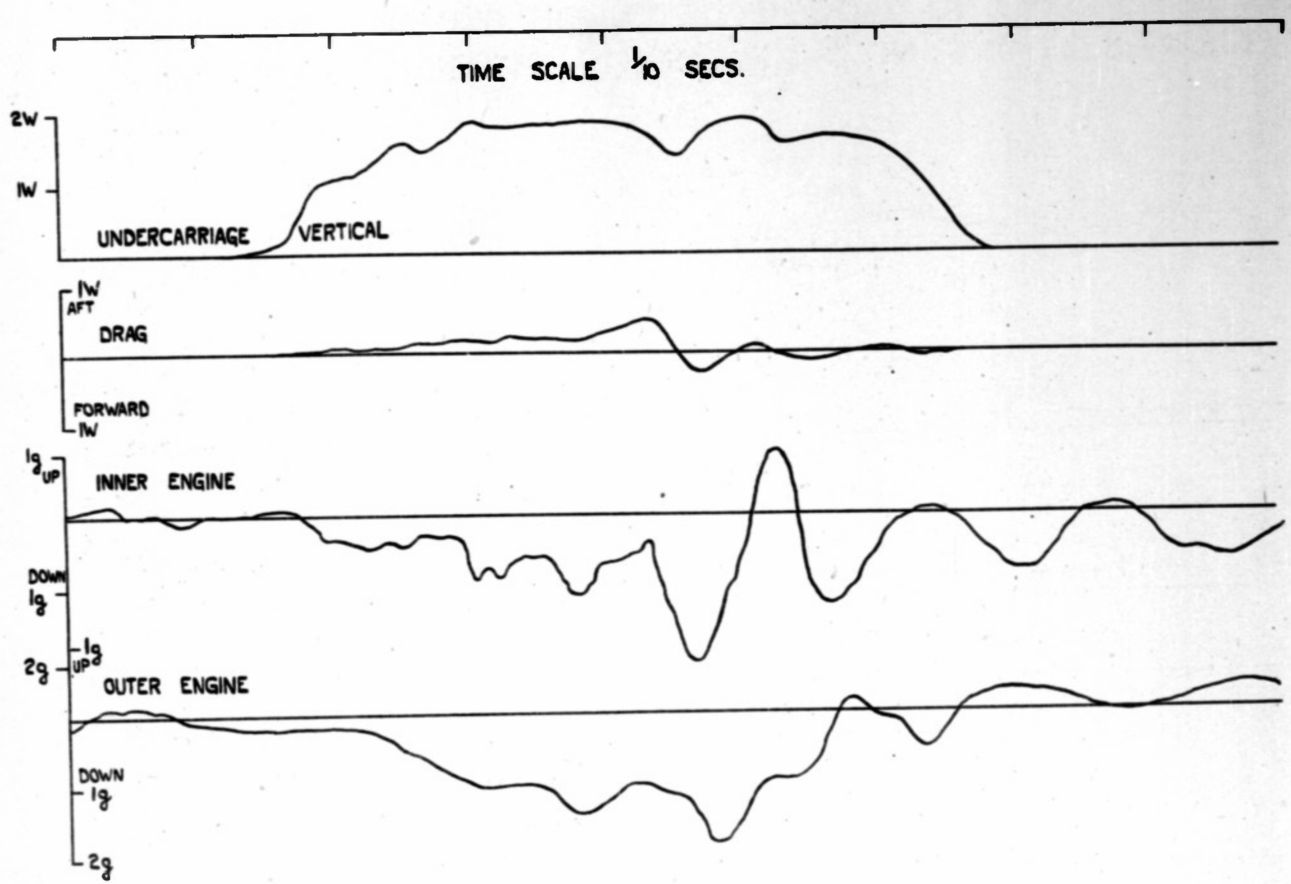


TRACING OF OSCILLOGRAPH RECORD DURING TOUCH DOWN ON LANCASTER ED.872, 16-4-45.

13-

T.N. S.M.E. 375.

FIG. 6.



TRACING OF OSCILLOGRAPH RECORD DURING TOUCH DOWN ON LANCASTER ED.872, 27-4-45.

14

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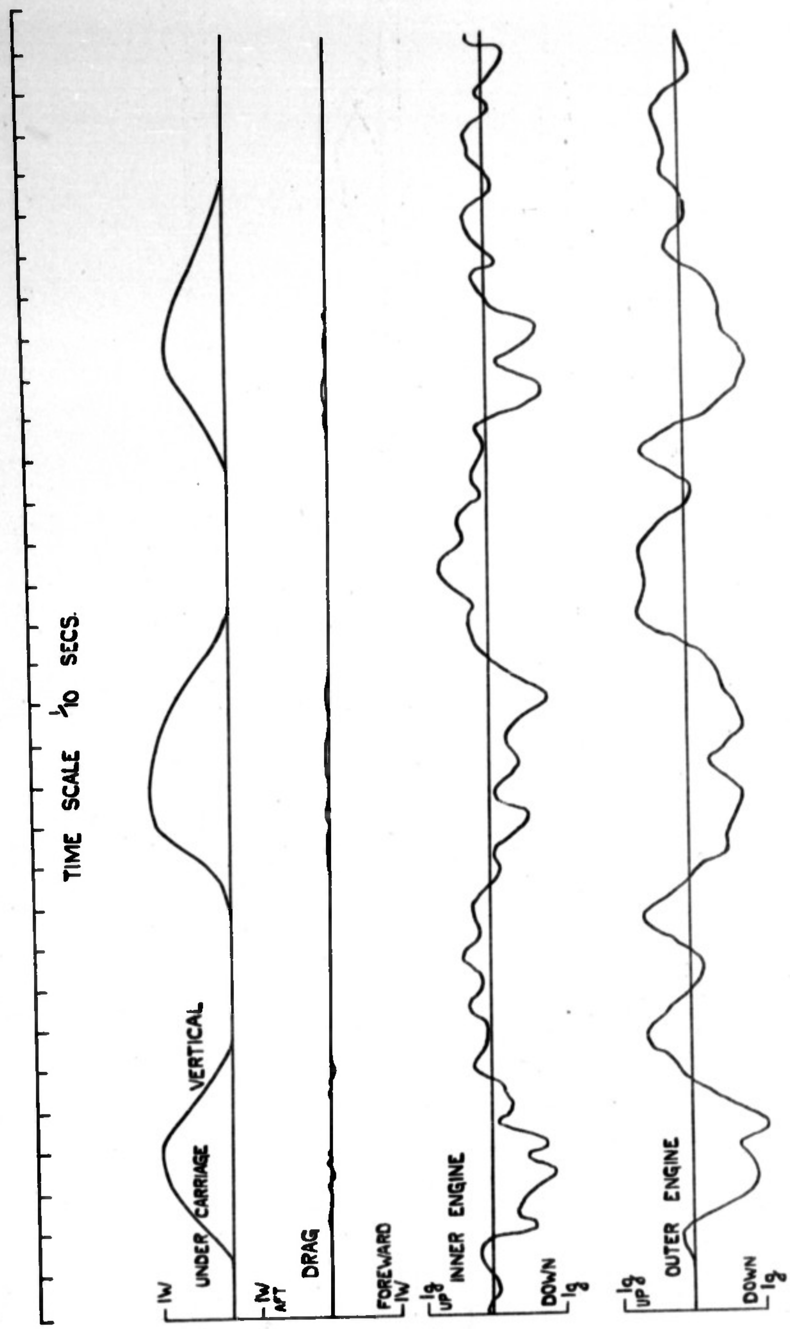
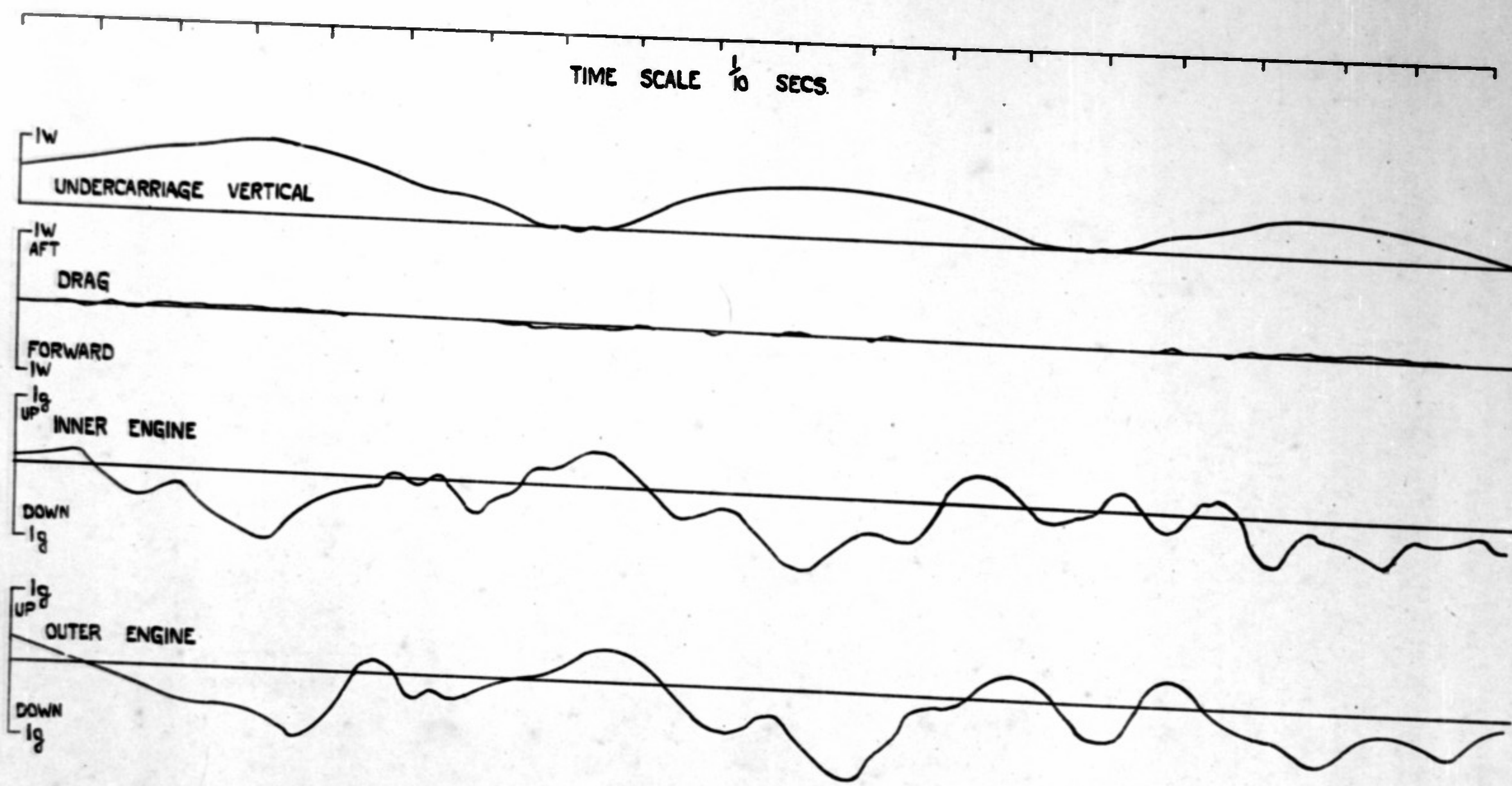
FIG. 7.



TRACING OF OSCILLOGRAPH RECORD DURING TAXYING ON LANCASTER ED.872, 19-4-45.

15—

FIG. 8.



TRACING OF OSCILLOGRAPH RECORD DURING TAXYING ON LANCASTER ED. 872 11-5-45.

16 —

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AUTHOR(S) : Lambie, J. B.

ORIG. AGENCY : Royal Aircraft Establishment, Farnborough, Hants

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